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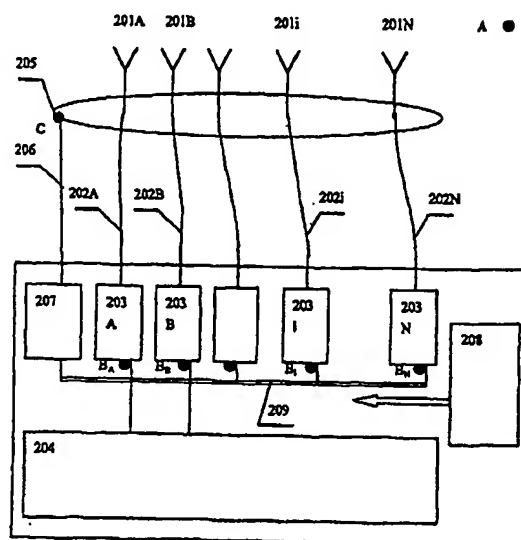
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**(54) METHOD AND APPARATUS FOR CALIBRATING SMART ANTENNA ARRAY**

(57) This invention discloses a method and a device for calibrating smart antenna array, which is used to calibrate smart antenna array in real time, comprising: setting coupling structure, feeder cables and pilot transceiver together as a calibrating link; pre-calibrating the couple structure with vector network analyzer and recording its receiving and transmitting transmission coefficient respectively; making receiving calibration to smart antenna array by adjusting transmission coefficient of each receiving link and reference link to a same amplitude and phase difference  $\Phi$  is recorded and stored in baseband processor; making transmitting calibration by adjusting transmission coefficient of each transmitting link and reference link to a same amplitude and phase difference  $\Psi$  is recorded and stored in baseband processor. The coupling structure of the invention is implemented by pilot antenna using spatial couple mode or passive network.

FIG. 1



**Description****Field of the Technology**

5 [0001] The present invention relates generally to a smart antenna technology of wireless communication system, and more particularly to a method for calibrating smart antenna array, as well as to a device for calibrating smart antenna array.

**Background of the Invention**

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[0002] In modern wireless communication system, especially in CDMA wireless communication system, in order to raise system capacity, to raise system sensitivity and to have farther communication distance with lower emission power, smart antenna is used, in general.

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[0003] In the Chinese patent named "Time Division Duplex Synchronous Code Division Multiple Access Wireless Communication System with Smart Antenna" (CN 97 1 04039.7), a base station structure of wireless communication system with smart antenna is disclosed. It includes antenna array consisted of one or plural antenna units, corresponding radio frequency feeder cables and a set of coherent radio frequency transceivers. According to different response of each antenna unit in antenna array to signal received from user terminal, baseband processor gets space characteristic vector and direction of arrival (DOA) of the signal; then with correspondence algorithm, receiving antenna beam forming is implemented. Among them, any one of antenna unit, corresponding feeder cable and coherent radio frequency transceiver together is called a link. By using weight, which is got from up link receiving beam forming of each link, for down link transmitting beam forming, whole functionality of smart antenna can be implemented, under symmetrical radio wave propagation.

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[0004] In the said above Chinese patent, in order to make smart antenna combine receiving and transmitting beam accurately, the difference between each antenna unit, comprised the smart antenna array, radio frequency feeder cable and radio frequency transceiver should be known, i.e. difference of amplitude and phase variation after radio frequency signal passing each link should be known; and procedure of getting difference among links of the smart antenna system is just the one concerned by smart antenna calibration of the invention.

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[0005] Calibration of smart antenna array is a kernel technology of smart antenna, as characteristic of electronic elements, which comprise radio frequency system of smart antenna, especially active elements characteristic, is very sensitive to working frequency, environment temperature and working duration etc., characteristic variation of each link, caused by the reasons said above, is impossible the same, so calibrating smart antenna system must be taken at any time.

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[0006] In present, there are about two kinds of calibration method for smart antenna. One is direct measure method: measuring every set of radio frequency transceiver and getting data related to its amplitude and phase, then adding measured amplitude and phase characteristic of antenna unit and feeder cable to form a set of calibration data; calibration procedure of this method is very complicated, it is difficult to take all measure in field, especially for wireless communication systems have been putting into operation. Another method is calibrated by a pilot transceiver at antenna far-field region, but this method requires the pilot transceiver is located at far-field region without multipath propagation; this is also difficult to implement in practice. Therefore, disadvantage of these two methods said above is obvious.

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**Summary of the Invention**

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[0007] Therefore, an object of the invention is to provide a method and device for calibrating smart antenna array in real-time, thus smart antenna system is practicable; device of the invention is to make method of the invention work effectively.

[0008] A further object of the invention is to provide two design and calibration method of couple structure for calibrating smart antenna array, which make method of the invention work effectively.

[0009] A method of the invention for calibrating smart antenna array, comprising:

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1. set a calibration link consisted in connection of a coupling structure, a feeder cable and a pilot transceiver; the coupling structure is coupled with N antenna units of the smart antenna array and the pilot transceiver is connected to a baseband processor of base station by a digital bus;

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2. calibrate the coupling structure with a vector network analyzer before the smart antenna array is put into operation, record its receiving transmission coefficient and transmitting transmission coefficient respectively;

3. make receiving calibration, wherein it comprises: transmitting a defined voltage level signal at setting working carrier frequency by analog transmitter of the pilot transceiver, and making N receiving links, in calibrated base station, are put in receiving state; detecting output of each receiving link respectively by baseband processor in

base station and calculating ratio of each link transmission coefficient to reference link transmission coefficient during receiving, according to each receiving link output; controlling each receiving link output by controlling variable gain amplifier, in each link analog receiver, to make amplitude ratio of each link receiving transmission coefficient to reference link transmission coefficient equals to 1; recording and storing phase difference  $\Phi$  between each receiving link and reference link in baseband processor;

4. make transmitting calibration, wherein it comprises: making only one link is in transmitting state at one time and all other transmitting link are in closing state among N transmitting links, and receiving signals coming from each transmitting link respectively at set working carrier frequency by analog receiver, in the pilot transceiver; processing detected the signals by baseband processor of base station and calculating ratio of each link transmission coefficient to reference link transmission coefficient during transmitting; controlling output of each transmitting link by controlling variable gain amplifier, in each link analog transmitter, to make amplitude ratio of each link transmission coefficient to reference link transmission coefficient equals to 1, during transmitting; recording and storing phase difference  $\psi$  between each transmitting link and reference link in baseband processor.

**[0010]** The said calibrate coupling structure with vector network analyzer, wherein it comprises: set a pilot antenna and spatial coupling mode; the said vector network analyzer is connected to feeder cable terminal of pilot signal and antenna unit terminal of to be calibrated link, antenna unit terminal of non-calibrated link is connected to matched load, measure and record receiving and transmitting transmission coefficient of to be calibrated link under each necessary working carrier frequency; repeat steps said above until all receiving and transmitting transmission coefficients of N links have been measured and recorded.

**[0011]** The said calibrate coupling structure with vector network analyzer, wherein it further comprises: set a passive network coupling structure consisted of N couplers and a 1:N passive distributor/combiner connected with N couplers, the N couplers are connected with antenna terminal of the N antenna units of smart antenna array respectively, and output of the passive distributor/combiner is feeder cable terminal of pilot signal; the said vector network analyzer is connected to feeder cable terminal of pilot signal and antenna unit terminal of to be calibrated link, antenna unit terminal of non-calibrated link is connected with matched load, measure and record receiving transmission coefficient and transmitting transmission coefficient of to be calibrated link under each necessary working carrier frequency; repeat steps said above until all receiving transmission coefficient and transmitting transmission coefficients of N links have been measured and recorded.

**[0012]** A device of the invention for calibrating smart antenna array, wherein it comprises a having been calibrated coupling structure, a feeder cable and a pilot transceiver; the coupling structures are coupled on N antenna units of the smart antenna array, the feeder cable is connected with the coupling structure and the pilot transceiver, the pilot transceiver is connected to a baseband processor in base station by a digital bus.

**[0013]** The said coupling structure is a pilot antenna with spatial coupling mode, the pilot antenna is in working main lobe of radiation directivity diagram of the N antenna units, which compose the smart antenna array; antenna terminal of the pilot antenna is feeder line terminal of pilot signal.

**[0014]** When the N antenna units, which compose the smart antenna array, are omni-directional antenna, the said pilot antenna is located at any position of near field region of each antenna unit.

**[0015]** The said coupling structure is a passive network, wherein it includes N couplers, corresponding with the N antenna units of the said smart antenna array, and a 1:N passive distributor/combiner connected with the N couplers; the said N couplers are connected with antenna terminals of the N antenna units respectively, output of the said passive distributor/combiner is feeder line terminal of pilot signal.

**[0016]** The said pilot transceiver has a same structure as the radio frequency transceiver of base station, including a duplexer, a analog receiver connected with the duplexer, a analog transmitter connected with the duplexer, a analog-to-digital converter connected with the analog receiver and a digital-to-analog converter connected with the analog transmitter; radio frequency interface of the said duplexer is connected with feeder cable of the coupling structure, the said analog-to-digital converter and digital-to-analog converter are connected to the said digital bus.

**[0017]** In the said analog receiver, a variable gain amplifier, controlled by software, is set for controlling gain; in the said analog transmitter, a variable gain amplifier, controlled by software, is set for controlling gain.

**[0018]** The invention provides a method and device of smart antenna array calibration, comprising using pilot transceiver and a set of coupling structure coupled with smart antenna array, wherein the coupling structure includes two technical schemes: one uses a method of calibrating smart antenna system by a geometrical symmetric structure pilot antenna, located at near field region or far-field region, and a antenna array implementing the said method, wherein the pilot antenna and related calibrating software is a composed part of wireless base station; another one uses a passive network consisted of couplers and distributor/combiner to implement the coupling structure feeds and calibrates smart antenna array. Either of two technical schemes makes a base station with smart antenna be calibrated very easily at all times, makes radio frequency parts and elements be changed at all times, therefore, engineering practical problem of smart antenna system is solved thoroughly.

[0019] Method and device of the invention for calibrating smart antenna array mainly point to CDMA wireless communication system, but after simple changes the proposed method and device can also be used for calibrating smart antenna of FDMA and TDMA wireless communication system.

## 5 Brief Description of the Drawings

[0020]

Figure 1 is a principle diagram of wireless communication base station using method and device of the invention.

Figure 2 is a principle diagram of analog transceiver.

Figure 3 is a coupling structure diagram using pilot antenna.

Figure 4 is a connection diagram of coupling structure, in smart antenna array, consisted of distributor/combiner and coupler.

Figure 5 is another coupling structure of the invention.

Figure 6 is flowchart of coupling structure calibration procedure.

Figure 7 is flowchart of smart antenna calibration procedure.

## Embodiments of the invention

[0021] With embodiment and drawings, method and device of the invention is described in detail in the following.

[0022] Referring to Fig. 1, it shows a typical base station structure of wireless communication system, which uses method and device of the invention for mobile communication system or wireless user loop system, etc., with smart antenna. The base station structure except calibration part is similar with the base station structure introduced by Chinese patent named "Time Division Duplex Synchronous Code Division Multiple Access Wireless Communication System with Smart Antenna" (CN 97 1 04039.7). It mainly includes N numbers of identical antenna unit 201A, 201B, ..., 201N; N numbers of almost identical feeder cable 202A, 202B, ..., 202N; N numbers of radio frequency transceiver 203A, 203B, ..., 203N and a baseband processor 204. In all radio frequency transceivers 203, there are Analog-to-Digital Converter (ADC) and Digital-to-Analog Converter (DAC), so input and output baseband signals of all radio frequency transceiver are all digital signal; they are connected with baseband processor 204 by a high speed digital bus 209; they use a same local oscillator 208 to guarantee that each radio frequency transceiver works in coherence.

[0023] In order to implement smart antenna real-time calibration, based on this station structure, calibration link consists of coupling structure 205 (coupling radio frequency circuit), feeder cable 206 and pilot transceiver 207 is added according to different antenna array;

[0024] Coupling structure 205 is coupled with N feeder cables 202A, 202B, ..., 202N; feeder cable 206 is used for connecting coupling structure 205 and pilot transceiver 207; pilot transceiver 207 is connected with high speed digital bus 209, and uses a same local oscillator 208 with all radio frequency transceiver 203.

[0025] Referring to Fig. 2, it shows structure of radio frequency transceiver 203 or pilot transceiver 207 shown in Fig. 1. It includes duplexer 210, analog receiver 211, analog-to-digital converter 212, analog transmitter 213 and digital-to-analog converter 214. In analog receiver 211, a variable gain amplifier 215 (can be controlled by software), used to control its gain, is set. In analog transmitter 213, a variable gain amplifier 216 (can be controlled by software), used to control its gain, is set. Radio frequency interface 217 of duplexer 210 is connected to feeder cable 202 and 206 directly. Analog-to-digital converter 212 and digital-to-analog converter 214 are connected with baseband processor 204 through high speed digital bus 209.

[0026] In smart antenna system, which uses base station structure shown in Fig. 1, there are N transmitting and receiving links in total; anyone of them is consisted of connecting antenna unit (201A, 201B, ..., 201N), feeder cable (202A, 202B, ..., 202N) and radio frequency transceiver (203A, 203B, ..., 203N), besides there is a calibration link consisted of pilot transceiver 207 and corresponding coupling structure (205 and 206).

[0027] Suppose taking  $A^{\text{th}}$  link as reference link (any link can be selected as reference link), then calibrating smart antenna system is to get transmission coefficient amplitude and phase difference between other link and the reference link on set working carrier frequency, during receiving and transmitting; therefore, in the invention, calibration of smart antenna is whole system calibration including antenna feeder cable and analog transceiver.

[0028] Suppose taking point A at antenna far-field region in Fig. 1, and  $B_i$ , which is a baseband interface among  $B_A$ ,

$B_B, \dots, B_i, \dots, B_N$  of transceiver 203 in base station, as observation reference point, transmission characteristic of smart antenna is represented with following formulas:

$$\text{transmission characteristic of receiving link : } Ar_i = Sr_i \times R_i \times br \quad (1)$$

$$\text{transmission characteristic of transmitting link: } Bt_i = St_i \times T_i \times at \quad (2)$$

where  $i = 1, 2, \dots, N$  represent first to  $N^{\text{th}}$  link respectively; in formula (1),  $Ar_i$  represents  $i^{\text{th}}$  link receiving signal at  $B_i$  point during point A emission,  $Sr_i$  represents degradation of  $i^{\text{th}}$  link reception by spatial propagation,  $R_i$  represents transmission coefficient when  $i^{\text{th}}$  link reception and  $br$  represents point A transmitting signal when reception; in formula (2),  $Bt_i$  represents received signal, at receiving point A, coming from  $i^{\text{th}}$  link, when point  $B_i$  emission,  $St_i$  represents degradation of  $i^{\text{th}}$  link transmitting by spatial propagation,  $T_i$  represents transmission coefficient when  $i^{\text{th}}$  link emission and  $at$  represents point  $B_i$  transmitting signal when emission. Both transmitting signal  $br$  and  $at$ , in two formulas respectively, are all digital signals, they should keep unchanged during calibration.

[0029] Calibration work of the invention is to get, with real-time measure, difference between  $i^{\text{th}}$  link transmission coefficient  $R_i, T_i$ , representing receiving and transmitting respectively, and transmission coefficient of reference link.

[0030] Basic means of the invention implementation is to move reference point A, said above, into antenna array, i. e., output terminal point C of feeder cable 206 in Fig. 1, by setting pilot transceiver 207, related feeder cable 206 and coupling structure 205; thus formulas (1) and (2) are rewritten respectively:

$$\text{transmission characteristic of receiving link: } ACr_i = Cr_i \times R_i \times br \quad (3)$$

$$\text{transmission characteristic of transmitting link: } BCt_i = Ct_i \times T_i \times at \quad (4)$$

where  $i = 1, 2, \dots, N$  represent first to  $N^{\text{th}}$  link respectively; in formula (3),  $ACr_i$  represents  $i^{\text{th}}$  link receiving signal at point  $B_i$  when point C emission,  $Cr_i$  represents transmission coefficient of the coupling structure when receiving test to  $i^{\text{th}}$  link; in formula (4),  $BCt_i$  represents receiving point C receives signal, coming from  $i^{\text{th}}$  link, when point  $B_i$  emission,  $Ct_i$  represents transmission coefficient of the coupling structure when transmitting test to  $i^{\text{th}}$  link.

[0031] If coupling structure is designed as a passive network, then this coupling structure has interchangeability, i.e.:

$$Cr_i = Ct_i = C_i \quad (5)$$

[0032] Replacing formula (5) into formulas (3) and (4), then following formulas can be got:

$$\text{Receiving link: } R_i = ACr_i / (C_i \times br) \quad (6)$$

$$\text{Transmitting link: } T_i = BCt_i / (C_i \times at) \quad (7)$$

[0033] In the invention, any link can be set as a reference link, suppose 1 link is set as reference link, then formulas (6) and (7) are changed to following formulas:

$$\text{Receiving link: } R_i / R_1 = ACr_i \times C_1 / (C_i \times ACr_1) \quad (8)$$

$$\text{Transmitting link: } T_i / T_1 = BCt_i \times C_1 / (C_i \times BCt_1) \quad (9)$$

where  $i = 2, 3, \dots, N$  represent second to  $N^{\text{th}}$  link, all of  $ACr_i, BCt_i, ACr_1$  and  $BCt_1$  can be measured in real-time,  $C_1$  and  $C_i$  can be calibrated beforehand and is defined by coupling structure, so  $R_i / R_1$  and  $T_i / T_1$  needed for smart antenna system calibration can be simply calculated.

[0034] Referring to Fig. 3, it shows a coupling structure of the invention, i.e., spatial coupling mode structure applying pilot antenna. Pilot antenna 230 is an antenna, which has relatively fixed physical position with the antenna array to be calibrated, the pilot antenna 230 must be in working main lobe of antenna unit radiation directivity diagram of antenna array. When each antenna unit is omni-directional antenna, pilot antenna can be set at any position including near field region of antenna unit.

[0035] Applying this coupling structure, the calibration method is: connect a Vector Network Analyzer 231 with pilot signal feed line terminal D of pilot antenna 230 and antenna terminal  $E_i$  of  $i^{\text{th}}$  to be calibrated link; at the same time, other antenna terminals of the to be calibrated antenna array such as  $E_1, E_2, \dots, E_N$  is connected to matched load 232A, 232B, ..., 232N respectively; then measure transmission coefficient  $C_i$  of  $i^{\text{th}}$  to be calibrated link with the vector network analyzer 231, after N numbers of measuring, transmission coefficients  $C_1, \dots, C_i, \dots, C_N$  of all link are got.

[0036] Advantage of this coupling structure is simple, when calibrating, non-consistency of every antenna unit has been considered; disadvantage of this coupling structure is position of pilot antenna is limited. Because pilot antenna should be set at far-field region of to be calibrated smart antenna array's working range, in order to guarantee calibration accuracy, it is very difficult to implement in practice. Therefore, only when antenna unit is an omni-directional antenna, pilot antenna is set at its near field region and its far-field region characteristic is replaced by its near field region characteristic, then calibration is practicable. For example, when using ring antenna array, pilot antenna can be set at the center of this ring antenna array, with its geometric symmetry to guarantee reliability of its near field region measure.

[0037] Referring to Fig. 4, it shows coupling structure of passive network 240, consisted of distributor/combiner and coupler, and its connection with smart antenna array 201A, 201B, ..., 201N. The coupling structure includes N couplers 242A, 242B, ..., 242N corresponding with N antennas 201, and a 1 : N passive distributor/combiner 241; each coupler of 242 is located at connection point  $E_1, E_2, \dots, E_N$  between each antenna unit 201A, 201B, ..., 201N and its feeder cable 202A, 202B, ..., 202N. The coupling structure has been independently calibrated before it is mounted in antenna array.

[0038] Referring to Fig.5, when applying coupling structure shown in Fig. 4, the calibration method is: connect a vector network analyzer 231 with pilot signal feed line terminal D of pilot antenna 230 and antenna terminal  $E_i$  of  $i^{\text{th}}$  to be calibrated link, at the same time, other antenna terminals of the to be calibrated antenna array such as  $E_1, E_2, \dots, E_N$  is connected to matched load 232A, 232B, ..., 232N respectively; then measure transmission coefficient  $C_i$  of  $i^{\text{th}}$  to be calibrated link with the vector network analyzer 231, after N numbers of measuring, transmission coefficients  $C_1, \dots, C_i, \dots, C_N$  of all link are got. Calibration method shown in Fig. 5 is same as calibration method shown in Fig. 3.

[0039] Passive network coupling structure, shown in Fig. 4, is more complex than pilot antenna coupling structure, shown in Fig. 3, and non-consistency of each antenna unit cannot be considered during calibration, but it can be conveniently used in calibration of any kind of smart antenna array.

[0040] Referring to Fig. 6, it shows calibration procedure with coupling structure, this calibration method can be used for both coupling structures shown in Fig. 3 and Fig. 4. Coupling structure has been calibrated before smart antenna array is put into operation, the got transmission coefficient C is kept in base station.

[0041] Step 601, calibration starts; step 602, calibrate first link of N links, i.e.,  $i = 1$ ; step 603, with connection mode shown in Fig. 3 or Fig. 5, calibrate first link; step 604, set first calibration frequency equals to first working carrier frequency of J working carrier frequencies, i.e.,  $j = 1$ ; step 605, set first link working carrier frequency equals to the first working carrier frequency; step 606, with vector network analyzer, measure transmission coefficient  $C_i$  of first link when calibration frequency equals to first working carrier frequency; step 607, record this measuring result; steps 608 and 611, by judging  $i = J?$  and calculating  $j = j + 1$ , repeat steps 605 to 608, which measure first link transmission coefficient at J numbers of working carrier frequency respectively, get and record transmission coefficient  $C_i$ ; steps 609 and 610, repeat measuring said above until measure of all working carrier frequencies is completed; and by judging  $i = N?$  and calculating  $i = i + 1$ , repeat steps 604 to 608, which measure transmission coefficient of N links for J numbers of working carrier frequency, and record measuring result.

[0042] Measure each link at each necessary carrier frequency and record all measuring results, then calibration of coupling structure is completed and whole transmission coefficients C is got.

[0043] Referring to Fig. 7, it shows whole procedure of smart antenna array calibration, before smart antenna array is put into operation, its coupling structure has been calibrated according to procedure shown in Fig. 6, and the got receiving and transmitting transmission coefficient C has been kept in base station, where the coupling structure is located.

[0044] Step 702, make receiving calibration first; step 703, transmitter of pilot transceiver transmits a defined voltage level signal with set working carrier frequency, in order to sure that receiving system of to be calibrated base station is working at normal working voltage level; step 704, all transceivers in receiving system of to be calibrated base station are at receiving state, i.e., N links are all at receiving state; step 705, each receiving link output is detected by baseband processor to make sure that system is working at set receiving level and each receiver is working at linearity region, according to output of each link receiver and formula (8) baseband processor calculates  $R_i / R_j$ ; steps 706 and 707, according to calculated  $R_i / R_j$ , by controlling variable gain amplifier (213 and 216 in Fig. 2) in each receiver, output of

each receiving link is controlled until  $|R_i / R_j| = 1$ ; record and store phase difference  $\Phi_i$  between each receiving link and reference link, in baseband processor, which will be used by smart antenna when working; step 708, when  $|R_i / R_j| = 1$ , shift to transmitting calibration; steps 709 to 715, when calibrating N transmitting links, receiver of pilot transceiver receives, respectively, signals coming from each transmitting link at set working carrier frequency; at this time among N transmitting links, said above, only one link is in transmitting state at one time and all others are in closing state (step 710); therefore, in each time, pilot receiver only receives signal coming from this link; right now, reference transmitting link must be measured and calibrated beforehand in order to make sure that its transmitting power is in rated voltage level; under this condition, receiver of pilot transceiver receives signal coming from every transmitting link (step 711); then baseband processor processes measured result and calculate  $T_i / T_j$  with formula (9) (step 714); after that, according to this value, output of each transmitting link is controlled by variable gain amplifier (211 and 215 in Fig. 2) of each transmitter until  $|T_i / T_j| = 1$  for each transmitting link (step 716); at the same time, phase difference  $\psi_i$  between each receiving link and reference link is recorded in baseband processor, up to now real-time calibration of smart antenna is completed.

[0045] Although method and device of the invention are proposed pointing to CDMA wireless communication system, but after simple changes, they can be used in FDMA and TDMA wireless communication system. Base station structure of wireless communication, shown in Fig. 1, is an example of TDD wireless communication system, but it can also be used in FDD wireless communication system. Any technician, whose career is research and development of wireless communication system, can implement smart antenna real-time calibration, after understanding smart antenna basic principle and referring to method and device of the invention.

## Claims

1. A method for calibrating smart antenna array, wherein the method comprises:

- 1) set a calibration link consisted in connection of a coupling structure, a feeder cable and a pilot transceiver; the coupling structure is coupled with N antenna units of the smart antenna array and the pilot transceiver is connected to a baseband processor of base station by a digital bus;
- 2) calibrate the coupling structure before the smart antenna array is put into operation, record its receiving transmission coefficient and transmitting transmission coefficient respectively;
- 3) make receiving calibration, adjust amplitude of each receiving link transmission coefficient and reference link transmission coefficient to make them equal, get phase difference  $\Phi$  between each receiving link and reference link, in order to be used when smart antenna is put into operation;
- 4) make transmitting calibration, adjust amplitude of each transmitting link transmission coefficient and reference link transmission coefficient to make them equal, get phase difference  $\psi$  between each receiving link and reference link, in order to be used when smart antenna is put into operation.

2. The method for calibrating smart antenna array according to claim 1, wherein it is **characterized** that: the said calibrate coupling structure uses a vector network analyzer.

3. The method for calibrating smart antenna array according to claim 1 or 2, wherein it is **characterized** that the said calibrate coupling structure with vector network analyzer comprises: set a pilot antenna and spatial coupling mode; the said vector network analyzer is connected to feeder cable terminal of pilot signal and antenna unit terminal of to be calibrated link, antenna unit terminal of non-calibrated link is connected to matched load, measure and record receiving and transmitting transmission coefficient of to be calibrated link under each necessary working carrier frequency; repeat steps said above until all receiving and transmitting transmission coefficients of N links have been measured and recorded.

4. The method for calibrating smart antenna array according to claim 3, wherein it is **characterized** that: the said pilot antenna is in working main lobe of radiation directivity diagram of N antenna units, which compose the smart antenna array; antenna terminal of the pilot antenna is feeder line terminal of pilot signal.

5. The method for calibrating smart antenna array according to claim 3, wherein it is **characterized** that: when the N antenna units, which compose the smart antenna array, are omni-directional antenna, the said pilot antenna is located at any position of near field region of each antenna unit.

6. The method for calibrating smart antenna array according to claim 1, wherein it is **characterized** that the said receiving calibration further comprises: transmitting a defined voltage level signal at setting working carrier fre-

quency by analog transmitter of the pilot transceiver, and making N receiving links, in calibrated base station, are put in receiving state; detecting output of each receiving link respectively by baseband processor in base station and calculating ratio of each link transmission coefficient to reference link transmission coefficient during receiving, according to each receiving link output; controlling each receiving link output by controlling variable gain amplifier, in each link analog receiver, to make amplitude ratio of each link receiving transmission coefficient to reference link transmission coefficient equals to 1; recording and storing phase difference  $\Phi$  between each receiving link and reference link in baseband processor.

7. The method for calibrating smart antenna array According to claim 1, wherein it is **characterized** that the said transmitting calibration further comprises: making only one link is in transmitting state at one time and all other transmitting link are in closing state among N transmitting links, and receiving signals coming from each transmitting link respectively at set working carrier frequency by analog receiver, in the pilot transceiver; processing detected the signals by baseband processor of base station and calculating ratio of each link transmission coefficient to reference link transmission coefficient during transmitting; controlling output of each transmitting link by controlling variable gain amplifier, in each link analog transmitter, to make amplitude ratio of each link transmission coefficient to reference link transmission coefficient equals to 1, during transmitting; recording and storing phase difference  $\psi$  between each transmitting link and reference link in baseband processor.
8. The method for calibrating smart antenna array According to claim 1 or 2, wherein it is **characterized** that the said calibrate coupling structure with vector network analyzer comprises: set a passive network coupling structure consisted of N couplers and a 1:N passive distributor/combiner connected with N couplers, the N couplers are connected with antenna terminal of the N antenna units of smart antenna array respectively, and output of the passive distributor/combiner is feeder cable terminal of pilot signal; the said vector network analyzer is connected to feeder cable terminal of pilot signal and antenna unit terminal of to be calibrated link, antenna unit terminal of non-calibrated link is connected with matched load, measure and record receiving transmission coefficient and transmitting transmission coefficient of to be calibrated link under each necessary working carrier frequency; repeat steps said above until all receiving transmission coefficient and transmitting transmission coefficients of N links have been measured and recorded.
9. A device for calibrating smart antenna array, wherein the device comprises: a having been calibrated coupling structure, a feeder cable and a pilot transceiver; the coupling structures are coupled on N antenna units of the smart antenna array, the feeder cable is connected with the coupling structure and the pilot transceiver, the pilot transceiver is connected to a baseband processor in base station by a digital bus.
10. The device for calibrating smart antenna array according to claim 9, wherein it is **characterized** that: the said coupling structure is a pilot antenna with spatial coupling mode, the pilot antenna is in working main lobe of radiation directivity diagram of the N antenna units, which compose the smart antenna array; antenna terminal of the pilot antenna is feeder line terminal of pilot signal.
11. The device for calibrating smart antenna array according to claim 10, wherein it is **characterized** that: when the N antenna units, which compose the smart antenna array, are omni-directional antenna, the said pilot antenna is located at any position of near field region of each antenna unit.
12. The device for calibrating smart antenna array according to claim 9, wherein it is **characterized** that: the said coupling structure is a passive network, wherein it includes N couplers, corresponding with the N antenna units of the said smart antenna array, and a 1:N passive distributor/combiner connected with the N couplers; the said N couplers are connected with antenna terminals of the N antenna units respectively, output of the said passive distributor/combiner is feeder line terminal of pilot signal.
13. The device for calibrating smart antenna array According to claim 9, wherein it is **characterized** that: the said pilot transceiver has a same structure as the radio frequency transceiver of base station, including a duplexer, a analog receiver connected with the duplexer, a analog transmitter connected with the duplexer, a analog-to-digital converter connected with the analog receiver and a digital-to-analog converter connected with the analog transmitter; radio frequency interface of the said duplexer is connected with feeder cable of the coupling structure, the said analog-to-digital converter and digital-to-analog converter are connected to the said digital bus.
14. The device for calibrating smart antenna array According to claim 13, wherein it is **characterized** that: in the said analog receiver, a variable gain amplifier, controlled by software, is set for controlling gain; in the said analog



transmitter, a variable gain amplifier, controlled by software, is set for controlling gain.

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FIG. 1

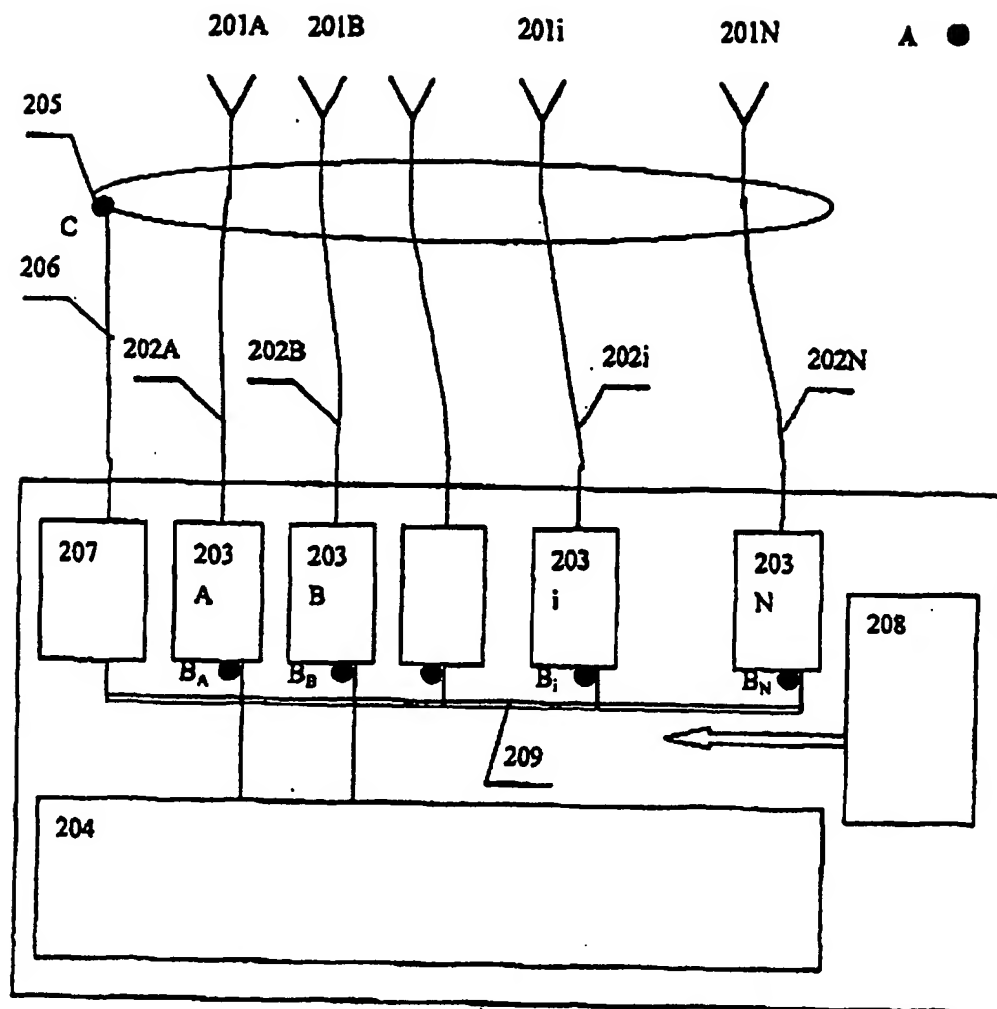


FIG. 2

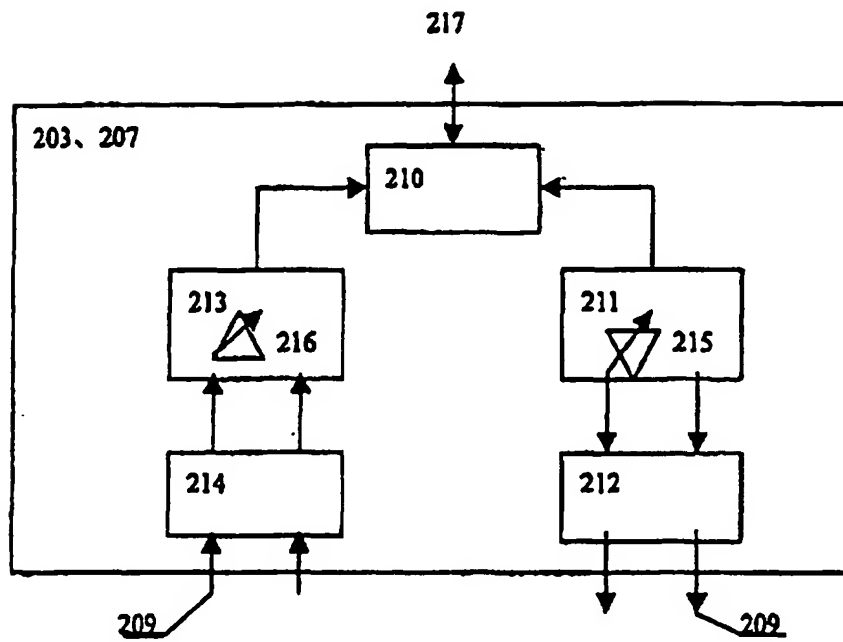


FIG. 3

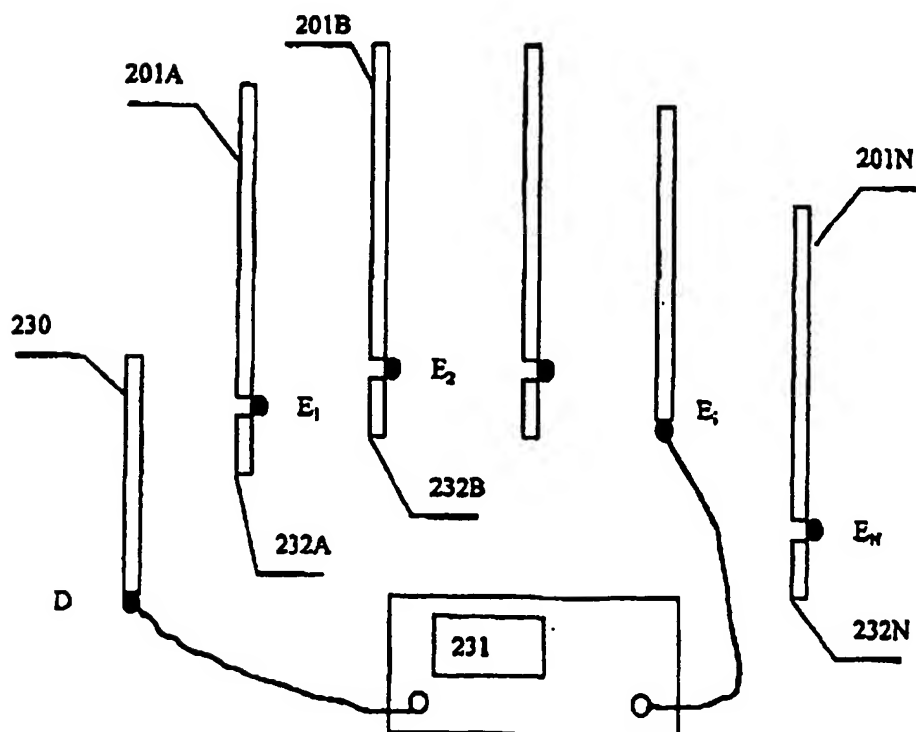


FIG. 4

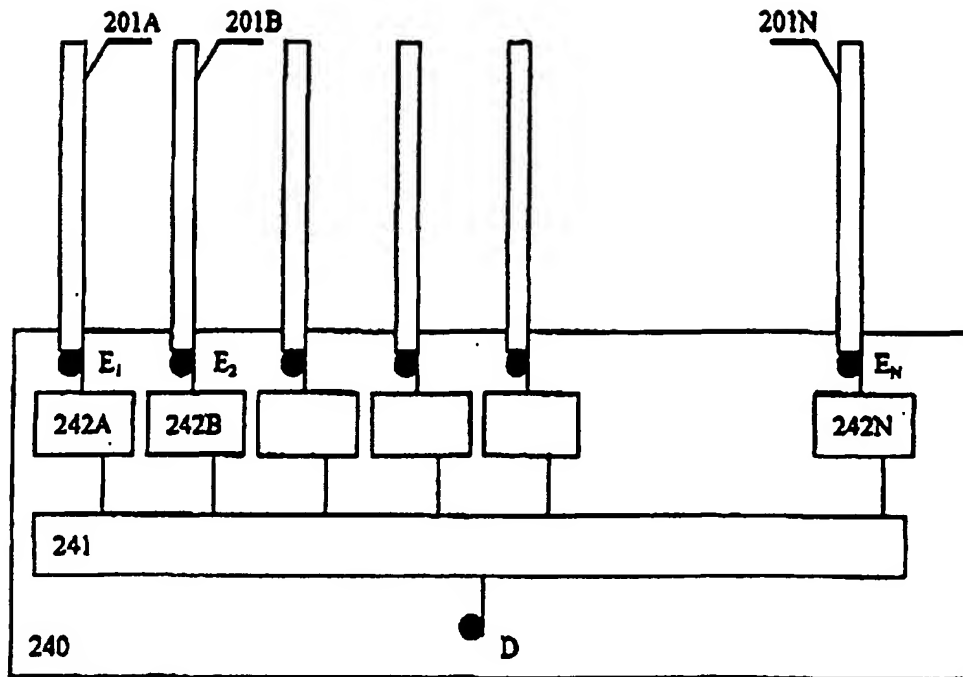


FIG. 5

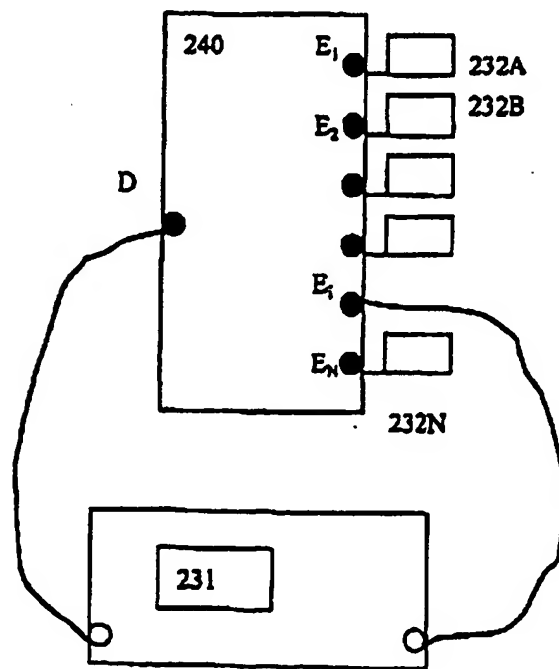


FIG. 6

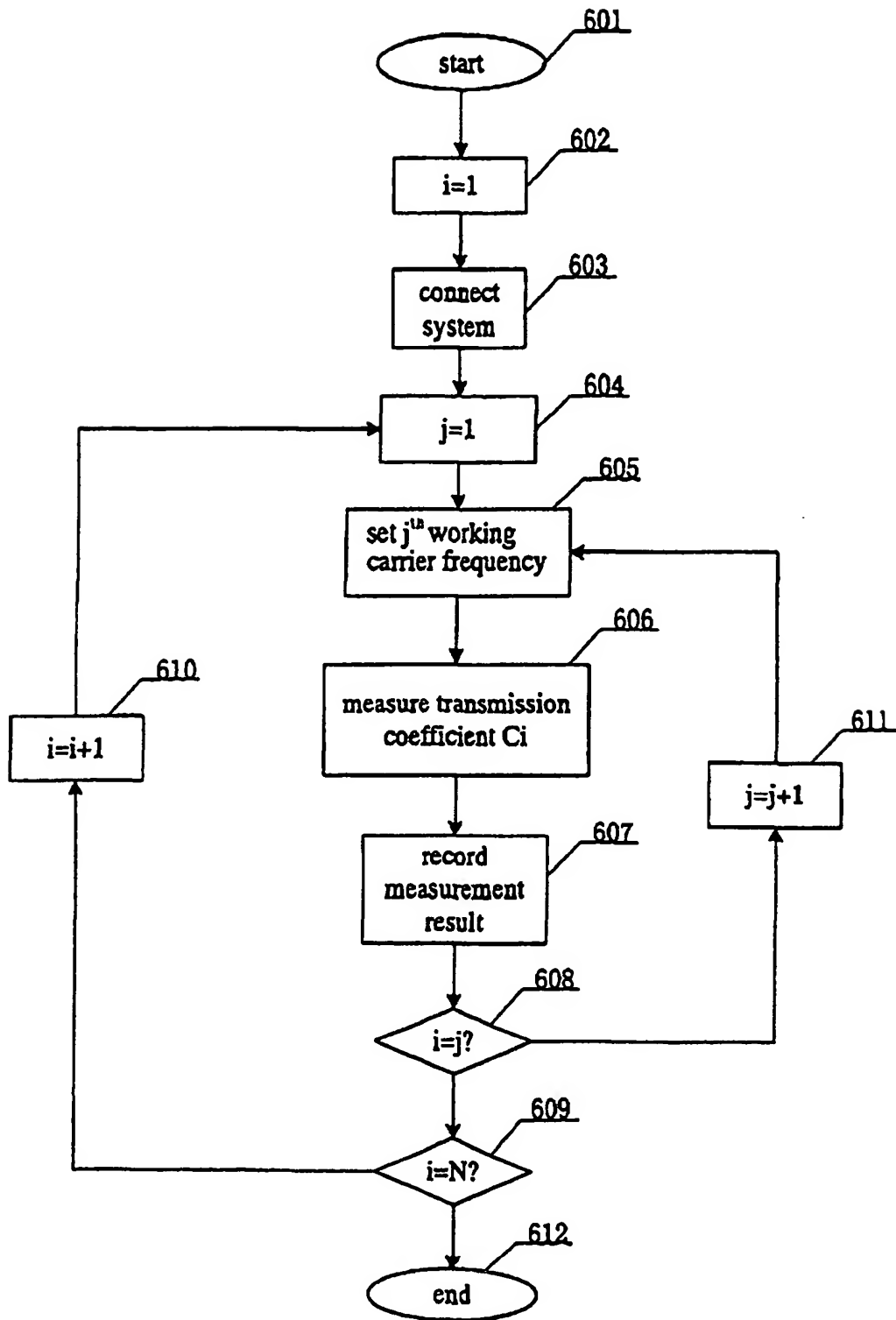
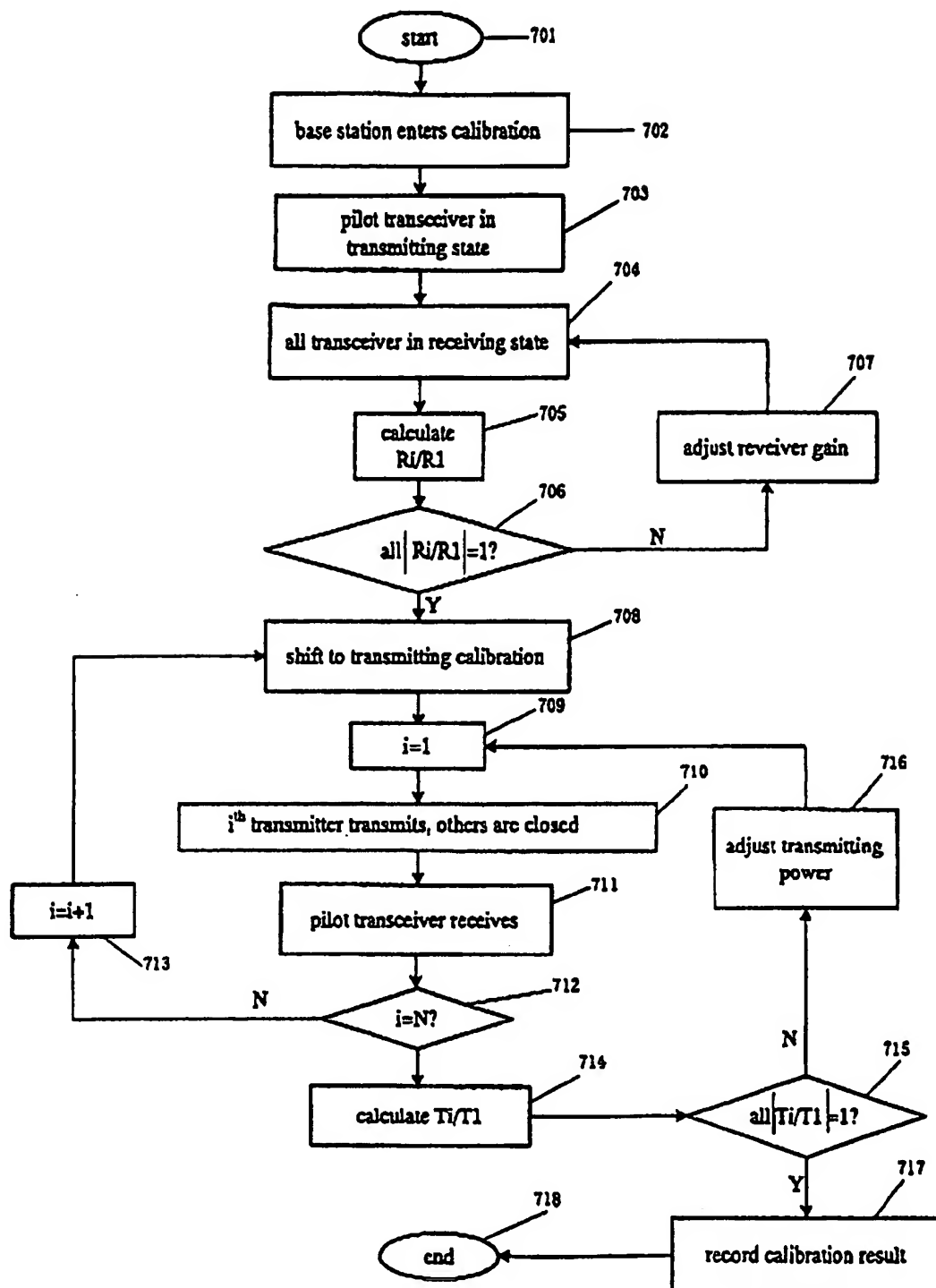


FIG. 7



## INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN00/00178

## A. CLASSIFICATION OF SUBJECT MATTER

IPC<sup>7</sup> H01Q3/26

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC<sup>7</sup> H01Q3/26 G01S13/74

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CN

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPODOC WPI PAJ CPOPAT

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US5546090 (ARRAYCOMM INC) 13.Aug.1996 (13.08.1996) Fig.4,6,7 and	1,2,9-11
Y	relating description	13,14
Y	WO95/34103 (TELEFONAKTIEBOLAGET LM ERICSSON) 14.Dec.1995 (14.12.1995) Fig2-5, description page 6	13,14
A	WO97/44920 (MOTOROLA LTD.) 27.Nov.1997 (27.11.1997) See whole document	1-14
A	EP415574 (GEC-MARCONI LTD.) 06. Mar. 1991 年 (06.03.1991) See whole document	1-14

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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Date of the actual completion of the international search  
28.Sep.2000(15.09.2000)

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